



## New and Existing Microelectronic Technologies

### Memory and Advanced Logic Devices

A. H. Johnston  
Jet Propulsion Laboratory  
California Institute of Technology  
Pasadena, California

This research was carried out by the Jet Propulsion Laboratory, California Institute of Technology, under contract with the National Aeronautics and Space Administration, under the NASA Electronic Parts and Packaging Program (Code AE).

5/17/00

1



## New and Existing Microelectronic Technologies

### Advanced DRAMs

- Critical for solid-state recorders and other advanced applications
- Lead state-of-the-art in device development

### Flash Memories

- Extremely high storage density
- Non-volatile feature very useful for space applications

### Other Non-Volatile Memory Technologies



## DRAM Charge Collection

---

Unusual Angular Dependence for High-Density DRAMs

Cross Section Varies by Several Orders of Magnitude

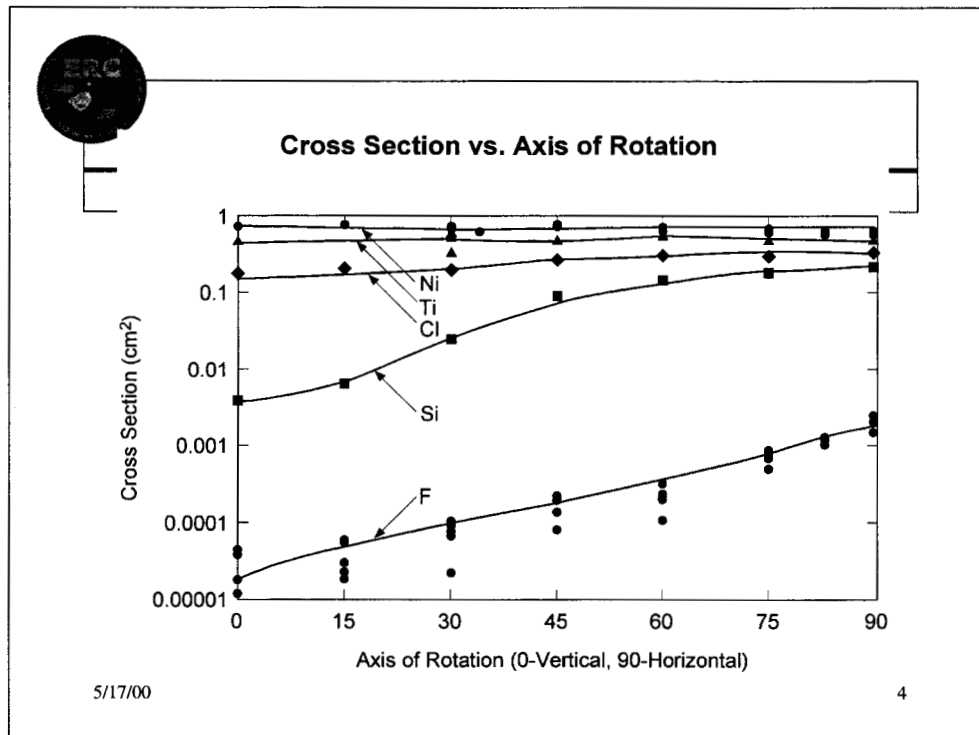
- Depends on angle of rotation as well as angle
- Attributed to geometrical layout of DRAM structures

Paper Accepted for NSREC 2000

- Modeling of response in progress
- Important factor in characterizing advanced DRAMs
- Upset rate can be seriously underestimated

5/17/00

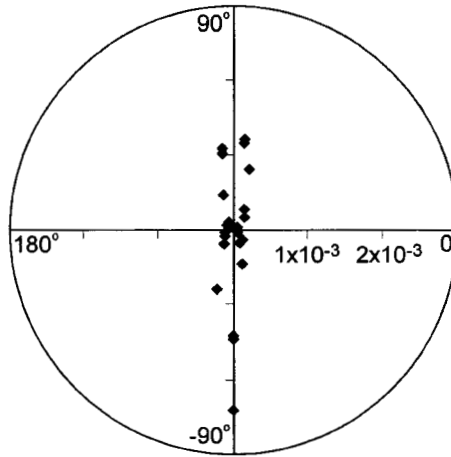
3



This slide shows the large difference in cross section that was observed when the devices were tested by varying the angle of incidence along the sensitive axis. The effect is most important at lower LET values that actually make a larger overall contribution to the total error rate in space.



### Cross Section vs. Azimuthal Angle for a Toshiba 64Mb DRAM Using F at 48° (polar plot)



5/17/00

5

This slide is a polar plot showing how the cross section varies for different angles when it is irradiated with fluorine atoms (LET approximately 4 MeV-cm<sup>2</sup>/mg). Note the extreme asymmetry of the results. There is less difference at higher LET values.

Older device types, such as the 4-Mb DRAMS that were carefully evaluated for solid-state recorder applications, showed results that were isotropic. Thus, this issue appears to be a new effect that is important for new DRAM technologies.



## Importance of DRAMs to Projects

---

### Solid-State Recorder Used in Many Missions

- Nearly all deep space missions
- Many earth-orbiting missions
- Require extremely high densities

### DRAMs Are also Used for Computer Memory

- Space shuttle
- Many other systems

### Advanced Architectures Complicate DRAM Radiation Issues

- Internal test modes
- Complex interface (i.e., synchronous DRAMs)

5/17/00

6



## Flash Memory Issues

---

### Severe Total Dose Sensitivity

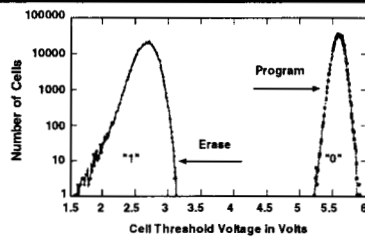
- High voltages required to write and erase cells
  - ~ 18 volts for NAND flash cells
  - ~ 12 volts for NOR flash cells
- Additional types of transistors added for higher voltages
- Internal charge pump used to generate voltage

### Flash Memory Technology Changes Rapidly

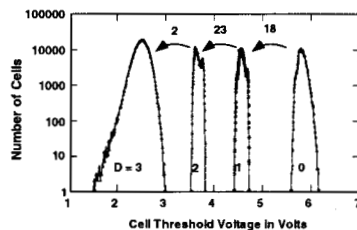
- Memories with 256-Mb now in production
- New design features
  - Multi-level storage technology
  - Complex internal architecture



## Multi-Level Flash Technology



(a) Single Level



(b) Multiple Level

5/17/00

8

This slide shows the distribution of internal threshold voltages for a conventional flash memory that stores either a “1” or “0” and the distributions for a multi flash memory with four distinct logic levels.

The multi-level flash technology has less margin between stored bits, and must incorporate analog circuitry within the memory to distinguish the four different logic conditions.





## Status of Flash Memory Work

---

Paper Accepted for 2000 NSREC

Work Is Continuing on Mechanisms and Modeling

- Investigation of charge pump degradation
- Comparison of 128-Mb technology with 32-Mb, 64-Mb

Evaluation of Wearout Effects

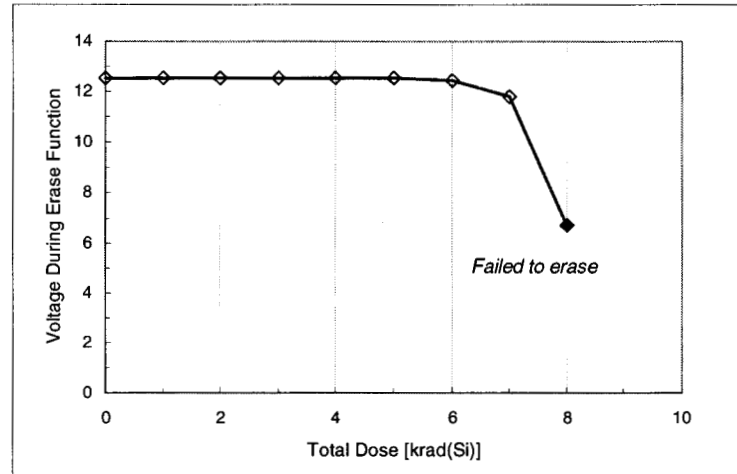
- Synergism between total dose degradation and wearout

5/17/00

9



### Erase Voltage vs. Total Dose for 128-Mb Samsung Flash Memory



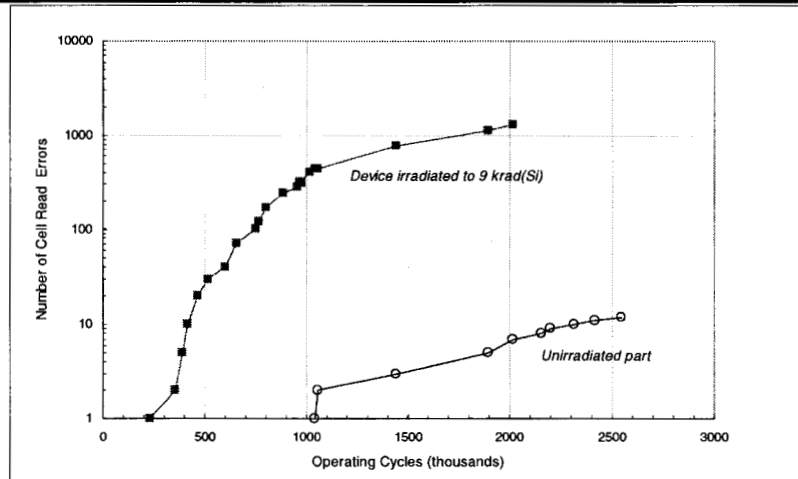
5/17/00

10

This slide shows how the internal voltage, developed by a charge pump, is affected when the device is irradiated with gamma rays. The charge pump voltage drops at the exact point where the circuits lose their ability to erase and write, although they will still work in the “read” mode.



### Effect of Wearout on Read Errors for Samsung 128-Mb Flash Memory



5/17/00

11

This slide shows how wearout of flash memories is affected by radiation damage. After irradiation to 9 krad(Si) the number of allowable read/write cycles has decreased by more than an order of magnitude.

This relationship is important for applications where very large numbers of read/write operations are planned, but will not affect flash memories that are used mainly in the "read" mode.



## Summary

---

### Advanced Devices Are Key Elements of the NEPP Program

- Enabling technologies for new spacecraft designs
- Critical for solid-state recorders and data processing

### Radiation Effects in Advanced Technologies Track Manufacturing Trends

- New mechanisms are often present
- Guide to effects of scaling and circuit design